# NISTTech

## HIGHLY CHARGED ION MODIFIED OXIDE DEVICE AND METHOD OF MAKING SAME

**Adjustable resistance semiconductor devices for magnetic disk storage**

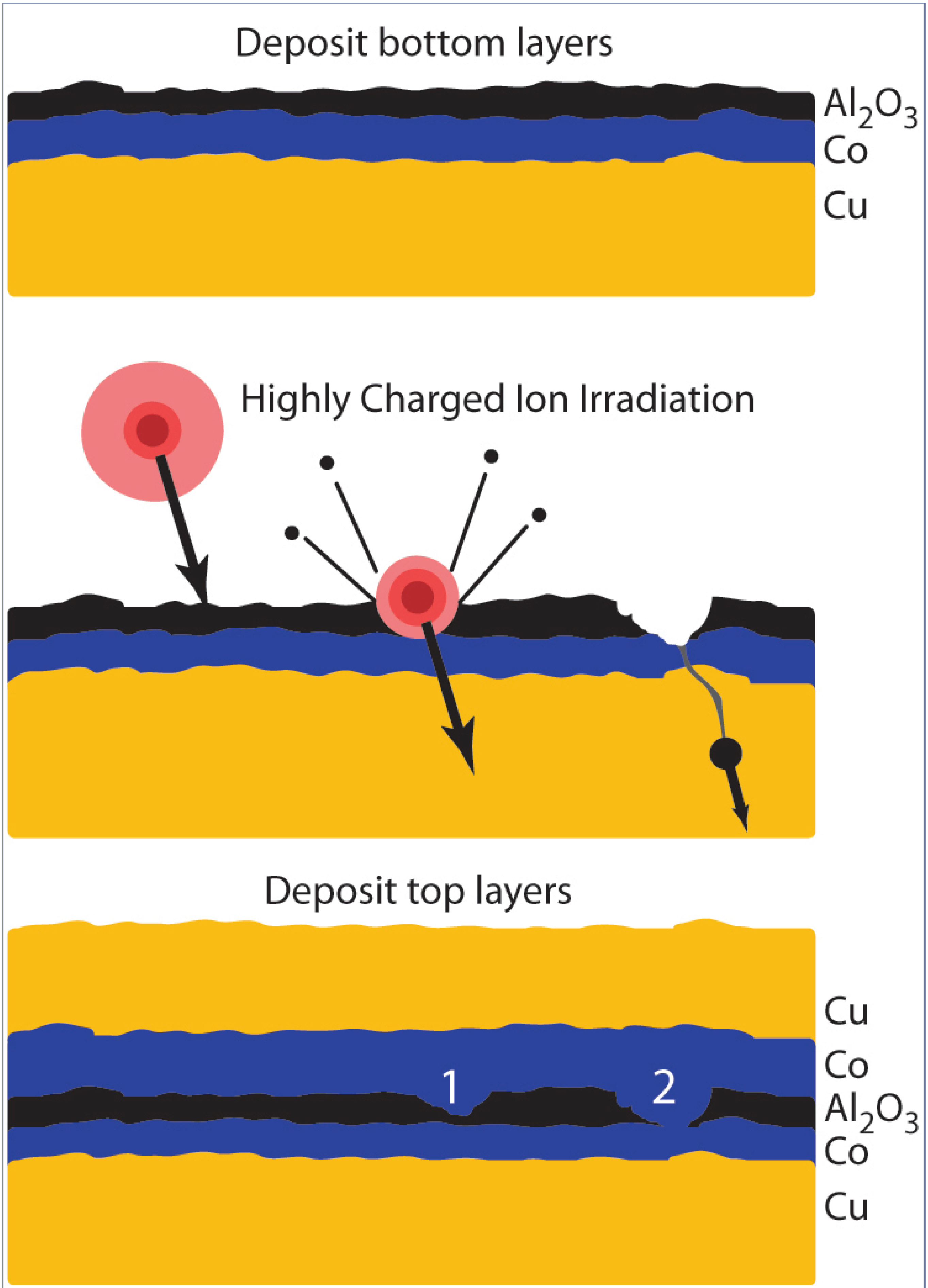
## Description

A process for adjusting the resistance of semiconductor devices by carpeting a small area of the device with tiny pits may be the key to a new class of magnetic sensors, enabling new, ultra-dense data storage devices. The technique allows engineers to tailor the electrical resistance of individual layers in a device by altering only a single step in the fabrication process. This is an important consideration for future scale-up, and can be applied to any device where it's desirable to fine-tune the resistance of individual layers.

As manufacturers strive to make disk storage devices smaller and more densely packed with data, the sensors need to shrink as well. To meet the size constraints, prototype sensors measure sensor resistance perpendicular to the thin layers, but depending on the buffer material in the sensor, two different types of sensors can be made. Giant magneto-resistance (GMR) sensors use a low-resistance metal buffer layer and are fast, but plagued by very low, difficult to detect signals. On the other hand, magnetic tunnel junction (MTJ) sensors use a relatively high resistance insulating buffer that delivers a strong signal, but has a slower response time that is too slow to keep up with a very high-speed, high capacity drive.

The NIST approach is to combine these at the nanometer scale. Starting with a magnetic tunnel junction - an insulating buffer - and using highly charged ions, little pits are blown into the buffer layer so that when the rest of the sensor is grown on top, the pits will act like little GMR sensors, while the rest will act like an MTJ sensor. The combined signal of the two effects should be superior to either alone.The NIST team has demonstrated the first step - the controlled pockmarking of an insulating layer in a multi-layer structure to adjust its total resistance. NIST researchers now are working to incorporate these modified layers into working magnetic sensors.

## Images




Top: Cu and Co layer, with insulating buffer layer of Al2O3. Mid: Highly charged Xe +44 ions strike buffer, digging nanoscale pits. Bottom:

layer of Cu and Co deposited on top.

## Applications

- **Any semiconductor device or magnetic sensor**
  Fine tuning electrical resistance applies to almost any type of semiconductor device or magnetic sensor that relies on sensing changes in an electronic signal.
- **Magnetic storage and sensors**
  Applicable in the magnetic storage industry, enabling new, ultra-dense data storage devices. May be the key to creating a new class of magnetic sensors.

## Advantages

- **MRAM protection**
  Nanoscale blasting adjusts resistance in magnetic sensors with up to three orders of magnitude control.
- **Simple fabrication process**
  Electrical resistance of specific layers in a device can be altered in a single step of the fabrication process.
- **Broad scope**
  Can be applied to any device where fine-tuned resistance is required of nanolayers. Decouples final electrical resistance from the electrical resistance of the individual source materials, producing a hybrid material.

## Abstract

Highly Charged Ion Modified Oxides (HCIMO) are achieved by irradiating a thin, high resistance oxide with highly charged ions (HCIs) and then depositing a conducting material of choice on top the irradiated oxide. The irradiation by HCIs preferentially ablates a region on the order of a cubic nanometer at each HCI's impact site breaking a hole through the ultra-thin oxide. This is demonstrated by the inventors by preparing an insulating layer of aluminum oxide on a cobalt lower electrode layer, exposing the oxide to very dilute HCI radiation, and then depositing a cobalt upper layer. The data show a clear and systematic decrease in the resistance of the multilayer devices correlated to the HCI dose at very dilute doses, i.e., an HCI density of 100 HCIs/ìm$^2$ (108 HCIs/mm$^2$) yields a resistance reduction by a factor of greater than 100. The nanometer dimensions of individual HCI impacts and the precise control over the dose combine to allow high precision selection of the material's resistance over a wide range of values, currently demonstrated over three orders of magnitude.

As HCI modification only occurs within a few nanometers of the surface and generally does not affect metals, no special measures are needed to protect surrounding device structures from HCI damage. Since the size of the material modification is determined by the properties of a single ion, precise alignment is not required, only uniform illumination of the device area by the HCI beam, greatly simplifying commercial integration of HCI irradiation.

We have further employed this strategy of producing an ensemble of small, discrete pockets of one material within another using HCIs to produce a new type of magnetic sensor. This approach may provide a solution to the current perpendicular to the plane (CPP) magnetic sensor resistance problem. In that problem, state-of-the-art CPP type magnetic sensors produced by using metal-metal interfaces or metal-insulator interfaces lead to resistances too low or too high, respectively, to be commercially viable. By using HCIMO as the buffer material instead of a metal (as in giant magneto-resistance [GMR] type sensors) or an insulator (magnetic tunnel junction [MTJ] type sensor) we can produce devices with the desired resistance values needed for advanced magnetic sensors for future hard drive read heads.

By using HCIMO as the buffer layer in a magnetic multilayer structure, we are creating a new type of sensor that uses a superposition of metal-insulator and metal-metal sensor junctions at a controlled density without advanced fabrication techniques. Magnetic sensitivity in this new type of device has also been demonstrated with evidence that both the metal-insulator and metal-metal parts of the HCIMO type sensors produce a clearly measurable response to small external magnetic fields.

## Inventors

- Pomeroy, Joshua M.
- Grube, Holger
- Perrella, Andrew

## Related Items

- Article: Nanoscale Blasting Adjusts Resistance in Magnetic Sensors
- MERWYN Business Simulation Report

## References

- U.S. Patent # 7,914,915 issued 9/11/2008, expires 10/29/2028
- Docket: 07-003

## Status of Availability

This invention is available for licensing exclusively or non-exclusively in any field of use.

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